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Electromyographic (EMG) Analysis of Trunk Muscles at the Point of Puck Contact during Slap and Wrist Shots of Female Ice Hockey Athletes

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ELECTROMYOGRAPHIC (EMG) ANALYSIS OF TRUNK MUSCLES AT THE
POINT OF PUCK CONTACT
DURING SLAP AND WRIST SHOTS OF FEMALE ICE HOCKEY ATHLETES

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A Scholarly Project

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School of Medicine

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for the degree of


Doctor of Physical Therapy

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This Scholarly Project, submitted by Lon Donald, Kristi Kjellgren, Jodi Young and Michael Young in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.


(Graduate School Advisor)


(Chairperson, Physical Therapy)

PERMISSION

Title Electromyographic (EMG) Analysis of Trunk Muscles at the Point of Puck Contact During Slap and Wrist Shots of Female Ice Hockey Athletes

Department Physical Therapy

Degree Doctor of Physical Therapy

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Date 12-15-04

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ABSTRACT

The number of female hockey players has increased significantly in the last decade. The first recorded female hockey game was in Ottawa in 1889. Since that time, hockey has spread into the United States. Today, USA Hockey, Inc. reports 40,000 registered females and the Canadian Hockey Association has 55,000 female hockey players. Despite the rising popularity of the sport among females, there is little research specifically related to female hockey players.

Golf, tennis, and hockey swings utilize similar rotational components about the trunk. Trunk rotation is controlled and produced by the erector spinae, external oblique and rectus abdominus muscles. Research related to trunk muscle activity has been conducted in tennis and golf, but there is a lack of information related to trunk muscle activity in female hockey players. The purpose of this study is to investigate EMG activity of the erector spinae, external oblique and rectus abdominus muscles in elite collegiate women hockey players during wrist and slap shots.

Seven females, ages twenty to twenty two, from a Division I women's hockey program were fitted with surface EMG electrodes prior to performing three wrist shots and three slap shots. The EMG activity from the erector spinae, external oblique, and rectus abdominus was rectified, normalized to MVC, and smoothed using RMS at 50 ms. Mean EMG activity was operationally defined as the average EMG activity of all the wrist shots or slap shots taken by each subject. Statistical analysis using a repeated

measures ANOVA was performed to assess differences between mean EMG activity of the wrist and slap shot, as well as between individual trunk muscles.

The results demonstrated no interaction of muscle and shot type on mean EMG activity. There was a significant increase ($p < 0.001$ with a power of 0.972) in mean EMG activity during the slap shot when compared to the wrist shot. Analysis of individual trunk muscles displayed no significant difference between muscles ($p = .233$). The higher velocity of movement during the slap shot may be responsible for the increase in EMG activity suggesting sport specific training activities should incorporate high speed activities.

CHAPTER I

INTRODUCTION

Women's hockey has recently emerged as a popular sport in both national and international competition. However, there is a paucity of information related to sport specific function in female hockey players. Specifically, the recruitment and activation pattern of the trunk muscles during two primary methods of scoring – slap shot and wrist shot – are missing.

Purpose

The purpose of this study was to quantify and qualify trunk muscle recruitment during two methods of scoring in hockey – slap shot and wrist shot. To accomplish this, EMG data was collected and analyzed with the Noraxon Myoresearch® system.

Significance

This study is important for the profession of physical therapy by providing information concerning muscle recruitment and activation of trunk muscles in women playing hockey. Results from this study, as well as future studies that may build upon this study, could be used for training and conditioning programs to improve the performance of hockey shots and possibly decrease injury rates during the female hockey shot.

Research Questions

1. What are the specific trunk muscle activation patterns in women during the performance of two hockey shots – slap shot and wrist shot?
2. Is there a significant difference in trunk muscle activation between the slap shot and wrist shot?

Null Hypothesis

1. There is no specific trunk muscle activation pattern in women during the performance of two hockey shots – slap shot and wrist shot.
2. There is no significant difference in trunk muscle activation between the slap shot and wrist shot.

CHAPTER II

LITERATURE REVIEW

In recent years, women's hockey has developed into a competitive and world recognized sport. The Olympics, Canadian National Women's Hockey League and intercollegiate programs in both the U.S. and Canada have helped develop female hockey and popularize the sport. Unknown to most, women have been playing hockey for over a century. The first recorded hockey game played by women occurred in Ottawa in 1889. Increasing in popularity, women's hockey spread across Canada and into the United States through the 1920's and 30's. However, following the depression and then the arrival of World War II, the teams and leagues began to dissipate and interest in women's hockey waned.¹

In the early 1960's, the sport was revived as women began to search out and gain equality. In the 1980's, Canada introduced women's hockey into their collegiate sport programs. The U.S followed suit in the 1990's as the NCAA began to recognize hockey as a female college sport. The year 1998 marked the first appearance of women's hockey in the Olympic Winter Games.¹

Two organizations that helped develop women's hockey within their respective countries are USA Hockey, Inc., and the Canadian Hockey Association. USA Hockey, Inc. is recognized as the national governing body for the sport of hockey in the United States. The Canadian Hockey Association is the official governing body of ice hockey

within Canada. Both of these organizations work closely with their respective Olympic Committees and the International Ice Hockey Federation (IIHF) to organize and train men's and women's teams for various international tournaments. Similarly, both of these organizations support and develop hockey teams and associations for competition within their countries at the collegiate, amateur, and professional levels. Current membership within USA Hockey, Inc. includes 585,000 ice and in-line hockey players, coaches, officials and volunteers.² The Canadian Hockey Association is a 538,152 member strong organization.³ As part of their combined efforts to support and develop women's hockey, USA Hockey, Inc. and the Canadian Hockey Association have tracked and reported the history and growth of women within the sport.

As reported by USA Hockey, Inc. and the Canadian Hockey Association, women of all ages are currently participating on both women's only and mixed gender teams. At this time, more than 40,000 females are registered with USA Hockey, Inc., compared to approximately 5,000 in 1990. The Canadian Hockey Association reports that there are nearly 55,000 female hockey players registered with Canadian based hockey teams. Although significantly less than their North American counterparts, Finland female hockey players have increased in number to about 2,200. It is anticipated that these numbers will only multiply in the coming years and that women's hockey will be one of the fastest growing sports in the world.⁴

As hockey becomes more prevalent in women's sports, research surrounding various aspects of the sport will become increasingly relevant and valuable. As in other sports, research and development of equipment has certainly played a role in advancing the sport to its current level. Originally, hockey skates consisted of blades that were

strapped to one's boots. The hockey stick used to be fashioned straight from tree branches. Today, the skates used in hockey are specifically designed for the type of position one plays and for the skill level of the individual player. Hockey sticks are now designed with performance minded curves and molded out of specially designed composite materials, promoting higher velocity and improved accuracy to one's shot.⁵

Just as research and development in hockey equipment technology can lead to advancements in the performance of hockey players, so can research in the biomechanics and muscle activity utilized by the actual athlete. Numerous studies in other sports have focused on the possibilities of improving the athlete through the study and research of human musculature. Yamanouchi⁶ evaluated the muscle activity of the lower extremities during baseball pitching to determine what hip musculature could be strengthened to directly lead to improvements in performance. Electromyography (EMG) has been used in the research of female basketball players to determine the role of the quadriceps in increased risk of ACL injuries.⁷ The overhead throwing motion of football quarterbacks has been investigated, providing clearer explanations of muscle activation patterns and subsequently a better understanding of muscle injury patterns and improvements in rehabilitation protocols.⁸ Similarly, muscle activation studies within the sport of female hockey could lead to a better understanding and advancements within the sport.

There are three main shots in hockey: the wrist shot, backhand, and slap shot. Each shot has a specific use throughout the game. The wrist shot and backhand vary in speeds depending on the use, either as a pass or an attempt to score. The slap shot is a high velocity shot primarily used to score. The whole body is used throughout each shot. The legs are used for balance as well as power during push off. The trunk is used during

the wind up and rotational acceleration. The arms supplement the wind up and swing through.⁹ The body and player's stick are used as one unit to gather energy and displace it in a perfectly timed motion to accelerate and place the puck where it is desired.

Each hockey shot can be divided into six components: preparation, windup, downswing, loading the stick, impact, and follow-through.⁹ During preparation, the player positions the puck in front of the skate closest to the target. This optimizes the amount of energy that will be transferred to the puck on impact. The position of the puck will also determine the height of the shot and is directed by the leading shoulder which is pointed in the direction of the desired destination. The windup consists of drawing the player's stick back by raising the posterior arm and rotating both the trunk and hips away from the puck. The rotation develops increased trunk, hip, and shoulder muscle recruitment as the muscles are first stretched and then activated. The further back the stick is cocked during the windup, the greater the force generated throughout the shot. The third phase of the shot, the downswing, includes the most trunk rotation. The shooter rotates the hips, trunk, and shoulders causing the stick to accelerate forward and downward until the stick strikes the ice approximately four inches behind the puck. To load the stick, the shooter pushes his lower hand into the shaft of the stick while the upper end is close to his body, thus slightly bowing the stick and storing energy. Impact occurs as the blade catches the puck, releasing energy and accelerating the puck. At this time the shooter rotates the shaft of the stick forward so that the blade turns over and greater acceleration is applied to the puck. During the follow-through, the body continues to rotate and move forward so that the stick moves upward in front of the body. This component is used to maintain balance on the ice.

Surprisingly, male athletes have typically been studied in the past, and there are few, if any, articles including females in analysis of involved musculature in a golf swing, tennis serve or swing, and female hockey shot. The lack of information regarding activation of trunk musculature during different hockey shots in female players has been noted previously. At the same time, it is important that future investigations utilize reliable and valid measurement tools when assessing muscle recruitment within female hockey players. A recent study tested the reliability of EMG measures and torque measurements of isometric right and left axial rotation at 100, 70, 50, and 30% maximum voluntary contraction (MVC) in two testing sessions at least 7 days apart.¹⁰ It was demonstrated that the reliability of the EMG and torque measures in the trunk muscles were good to excellent. Another study was conducted to determine the short and long-term reliability of EMG measurements tested under constant, proper conditions.¹¹ The data revealed highly reliable short-term and acceptably reliable long-term EMG measurements both in the amplitude and frequency domains of the quadriceps muscle. Furthermore, 50% MVC EMG recordings demonstrated better reproducibility than 100% MVC measurements.¹⁰

The rectus abdominus, external oblique, and erector spinae muscles are often defined as core stabilizers.¹² Proper development of these muscles is crucial for any athlete's performance, particularly those who participate in high rotation/ballistic sports such as golf and tennis.¹³ Core stabilizers provide balance and rotational power through co-contraction to regulate rigidity within the trunk and between the trunk, lower extremities, and the playing surface. When this rigidity is achieved, it is possible to balance throughout a motion, produce power through contraction, and stabilize the body

extremities, and the playing surface. When this rigidity is achieved, it is possible to balance throughout a motion, produce power through contraction, and stabilize the body against an external force such as a ball or puck. Golf and tennis players perform motions which appear to be similar to shots performed by hockey players. Research using EMG activity has been performed to assess the core stabilizers' muscle activity in both the sport of golf and tennis.

It is important to understand the actions of each of the trunk and core stabilizing muscles and Table 2.1 includes the discussed muscles and their actions. These muscles were chosen because of their activity levels in golf and tennis swings. Hockey players appear to use similar mechanics when competing; therefore the rectus abdominus, erector spinae, and external oblique were chosen for this study.

Table 2.1. Selected muscles and their actions*

Muscle	Action
Rectus abdominus	Flexes trunk, compresses abdominal viscera
External oblique	Flexes and rotates trunk to the opposite side, compresses/supports abdominal viscera
Erector spinae	Bilaterally extends head and trunk, unilaterally assists in lateral flexion of the head and trunk

*Information taken from Moore¹⁴

In a study completed by Young-Tae,¹⁵ EMG of the rectus abdominus, external and internal oblique and erector spinae muscles was assessed during the four phases of a golf swing using one male subject. These phases include the take away, forward swing, acceleration and follow through which are very similar to the hockey shot. The external and internal obliques as well as erector spinae muscles demonstrated high EMG activity.

obliques, internal obliques, and erector spinae. This study did not assess the rectus abdominus muscle.¹⁶

One study looked at modifying the golf swing to help reduce injury.¹⁷ To do this, EMG analysis was performed on the external oblique, as well as the latissimus dorsi and right pectoral muscles on seven golfers (one woman and six men) during a regular full recoil swing and a modified short backswing. The outcomes indicated that using a short backswing instead of a full recoil swing may reduce trunk muscle activation. This information relates to the current study because there may be measurable and significant EMG differences between the two hockey shots under study.

Conversely, there may not be a measurable and significant EMG difference between hockey shots. This was shown in a golf study conducted by Watkins et al.¹⁸ Thirteen male professional golfers were studied and researchers concluded that there were repeatable patterns of trunk musculature activity throughout all phases regardless of differences in individual swings. Horton et al.¹⁹ conducted a study using eighteen male professional golfers and seven elite male amateur golfers with low back pain and a separate asymptomatic control group. They were interested in muscle activity and fatigue levels of the rectus abdominus and external and internal oblique muscles. Research indicates that no differences in EMG activity were present between the two groups.

The sport of tennis is another example of using rotational components of the trunk during the different swings, providing a similarity to ice hockey. Monitoring EMG activity of the rectus abdominus, external oblique, internal oblique and erector spinae indicated that there was indeed trunk activity with three different tennis serves while

observing five male intercollegiate tennis players.²⁰ The three serves observed were the flat, topspin and slice. However, with all three serves there were no major differences in muscle activation patterns.

Based on the above research, it appears that there are no differences in EMG activity with different tennis swings or serves, but there is some variance when looking at golf swings. Because of this information and the lack of current research regarding women's ice hockey, it is important to investigate the hockey slap shot, wrist shot and backhand and see what patterns of EMG activity develop. Therefore, the purpose of this research study is to investigate the EMG activity of core stabilizing musculature in women hockey players during two different shots.

CHAPTER III

METHODOLOGY

This project was reviewed and approved by the University of North Dakota Institutional Review Board prior to the initiation of the study (See Appendix A).

Subjects

A Division I women's hockey program was invited to participate in this research project. Participants from the hockey team met the following guidelines: no current injuries or medical conditions, female, over the age eighteen, and playing at one of the following positions- forward or defense. The voluntary participants in this study included seven adult females with varying levels of hockey participation. The subjects attended one day of testing using their personal hockey equipment including skates, gloves and hockey stick. All subjects completed an approved human subject consent form as well as an intake survey to determine the level of hockey experience after the study was explained and all questions were answered (See Appendix A).

Instrumentation

Self-adhesive, pre-gelled Ag/Ag EMG surface electrodes (Model #3BFEX, Multi Bio Sensors, Inc., El Paso, TX) with an inter-electrode distance of 3.2 cm were placed bilaterally over the rectus abdominus, external oblique, and erector spinae musculature. The EMG activity was collected using a TeleMyo 900 telemetry unit (Noraxon USA, Scottsdale, AZ). The EMG activity was transmitted from the telemetry transmitter to the TeleMyo 900 receiver which was interfaced with an analog to digital interface unit (Peak

Performance Inc., Englewood, CO) utilizing a NorBNC board (Noraxon USA). The data was viewed on a standard computer monitor prior to saving to the hard drive of a desktop (Peak Performance Technologies, Inc., 2.6 GHz Pentium 4) computer as a binary data file (Peak Performance Inc.). The EMG data files were then imported from the Peak Performance system into the Myoresearch XP software program (Noraxon USA) using a laptop computer (HP Pavilion ZV5000, Pentium 4 2.80 GHz processor). All further data analysis was performed using the MyoResearch XP (Noraxon, USA) software program.

Procedure

Prior to the initiation of the study, EMG equipment was set up and tested by the researchers to ensure proper signal transmission and reception. The subjects were tested independently at the University of North Dakota physical therapy department in Grand Forks, ND. The purpose and procedure of the study were explained to the subjects prior to each participant signing a statement of informed consent, completing an intake survey, and the initiation of data collection.

Subjects used their personal hockey sticks, skates and gloves and were dressed in loose, comfortable clothing during data collection. A standard hockey puck was used during this study. Electrode sites were prepared by shaving excess hair from the area with electric clippers, followed by cleaning with rubbing alcohol to ensure proper signal conduction. Surface electrodes (Multi Bio Sensors, Inc.) were placed bilaterally over the rectus abdominus, external oblique, and erector spinae muscles using points previously published in the literature (See Figure 3.1).²¹ The specific points were:

1. Rectus abdominus muscles, two cm lateral and two cm superior to the midpoint of umbilicus

2. External oblique muscles, five cm superior to the anterior superior iliac spine (ASIS)
3. Erector spinae muscles, aligned with L₃-L₄ vertebral interspace, four cm lateral to the midline
4. Ground electrode, right ASIS

The TeleMyo transmitter was secured to the dominant side of the subject.

Electrodes were then connected to the lead wires of the transmitter prior to testing the signal conduction to the receiver and collecting computer. Subjects performed manual muscle tests (MMT) bilaterally for each muscle to establish maximal voluntary contractions (MVC) for subsequent normalizing of EMG data allowing subject pool comparison. The rectus abdominus and external oblique muscles' maximal voluntary contraction was performed using a resisted partial sit up in the supine position while the erector spinae were tested in the prone position. The subject was instructed to contract the muscles as hard as they could while resistance was provided through the upper trunk. Each MMT was held for five seconds and EMG data was collected during this time. Subjects then donned their hockey skates and gloves and randomly selected the type of shot they would perform by drawing a number pre-assigned to a type of shot by the investigators.

Two types of shots were performed during this comparison study: the wrist shot and the slap shot. A make-shift platform was constructed for this study. The subjects were instructed to position themselves on the platform in a normal stance and shoot the puck approximately eight feet into a barrier of soft material. Each subject performed three warm-ups for both the wrist shot and slap shot prior to the collection of data. The

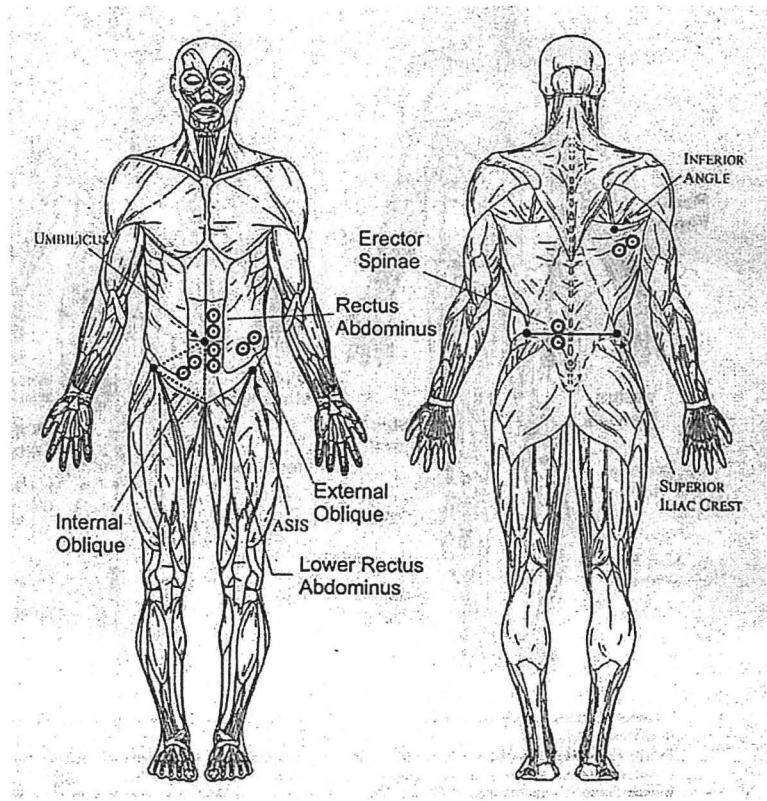


Figure 3.1. Electrode placement for rectus abdominus, external oblique and erector spinae.

warm-up period allowed the subject to become comfortable with the surrounding apparatus and allowed the researchers to assure appropriate EMG transmission.

Following the warm-up session, each subject performed three of the randomly selected shots and then the final three repetitions of the other type of shot. Subjects were instructed to perform each shot as though they were shooting in a game. Data from each shot was collected and saved for further analysis. The subjects were then disconnected from the transmitter. The electrodes were removed and the sites of transmission were cleaned.

As previously mentioned, the EMG data files were then imported from the Peak Performance system into the Myoresearch XP software program (Noraxon USA) using a laptop computer (HP Pavilion ZV5000, Pentium 4 2.80 GHz processor). Using the MyoResearch XP (Noraxon, USA) software program, the EMG data were integrated and smoothed. A root mean square (RMS) of 50ms was used to smooth the EMG signals. Each trial of the subjects was normalized to the MVC determined during the MMT of the muscles under investigation. The MVC was experimentally defined as the highest contiguous 1000 data points occurring during the five second MMT contraction collected for each muscle. Mean EMG activity for each shot was determined by averaging the repetitions of the shot. For each shot, the period of importance during the shot was operationally defined as 0.3 seconds before the point of contact and 0.5 seconds after the point of contact. This 0.8 second period of time appeared to sufficiently identify the highest peaks of EMG activity during the shots.

Statistical analysis of the averaged mean EMG activity was performed using a repeated measures ANOVA. Statistical significance was determined to be $p < 0.05$. All data are reported as mean \pm standard deviation.

CHAPTER IV

RESULTS

The subject group consisted of seven adult female Division I hockey players with an age range of twenty to twenty two years old (mean age = 20.7 ± 0.95), average weight of 143 lbs ± 13 , and average height of 64 ± 2 inches. The subjects reported playing competitive hockey for a range of six to thirteen years (mean years of playing = 10 ± 2 years). The subjects reported playing forward (4), wing (2), or defensive (1) positions. All subjects also reported playing at least one third of each scheduled game during the previous year of competition. Two subjects reported old injuries, one as a strained groin and the second with a scaphoid fracture in her dominant hand ten months previous. There was a zero drop out rate for the study.

EMG

The results of the EMG data were used to determine if there was a significant difference between each muscle (dominant and non-dominant rectus abdominus, external obliques, and erector spinae) during a slap shot versus a wrist shot, as well as any differences between the two shots in general. Significance in EMG activity of each muscle during each of the three shots was determined by analyzing the entire group of seven subjects collectively. Data from all seven subjects were assessed initially to determine if an interaction between shot type and muscle activity was present. In the

absence of an interaction, main effects of shot type and individual muscle EMG contribution was assessed.

A repeated measures ANOVA found a significant difference in EMG activity between the two types of shots, but not between individual muscles during each shot ($p < 0.05$). The significance level of EMG activity found between the slap shot and wrist shot was < 0.001 with a power of 0.972. There was no interaction between shot type and individual muscle ($p = 0.233$ and power of 0.447). Figures 4.1 through 4.7 display the EMG activity of each muscle during the control (MVC), slap shot, and wrist shot.

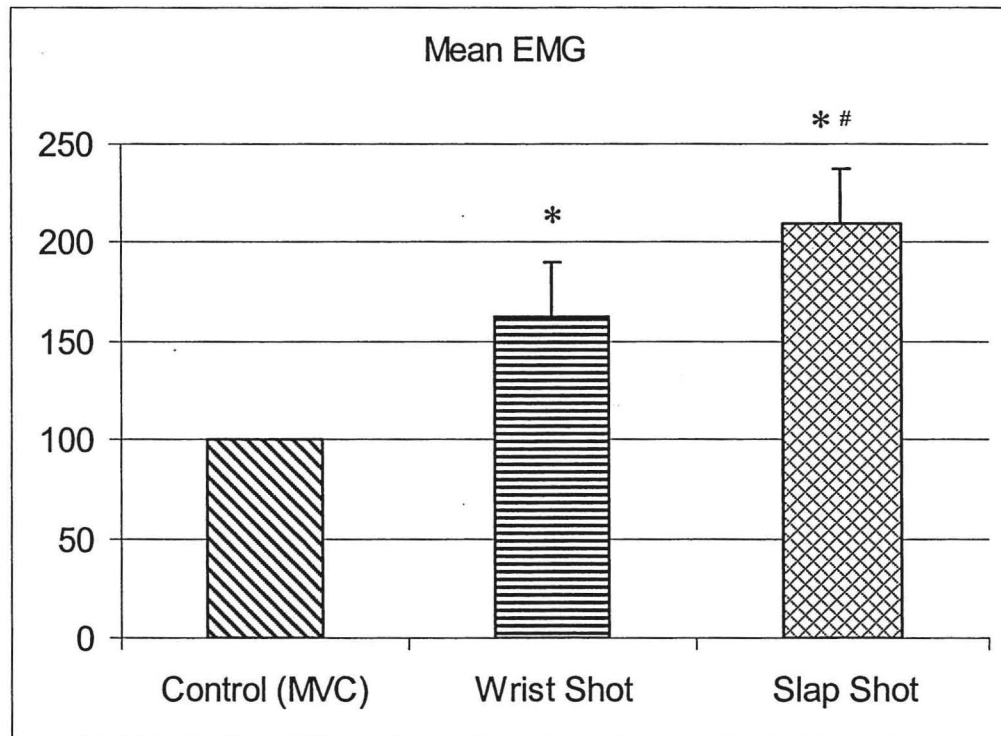


Figure 4.1 Mean EMG activity between different shots (n=7 in all cases)

* = $p < 0.05$ between MVC and shots

= $p < 0.05$ between wrist and slap shot

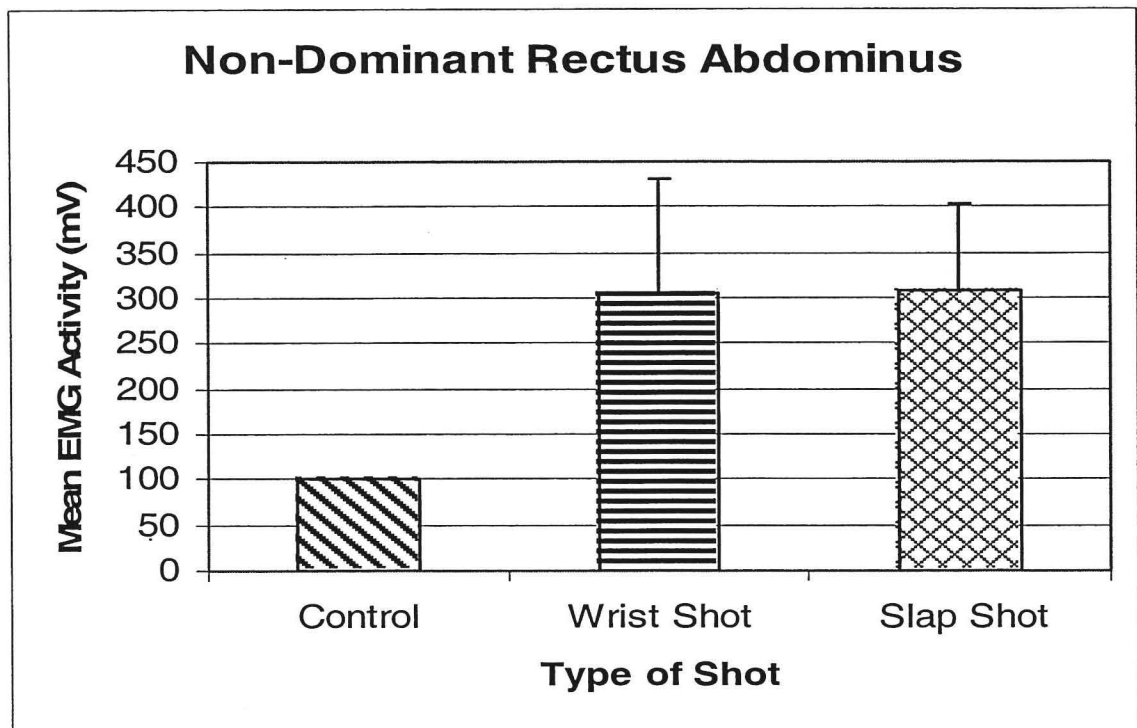


Figure 4.2. EMG activity of non-dominant rectus abdominus during shots (n=7)

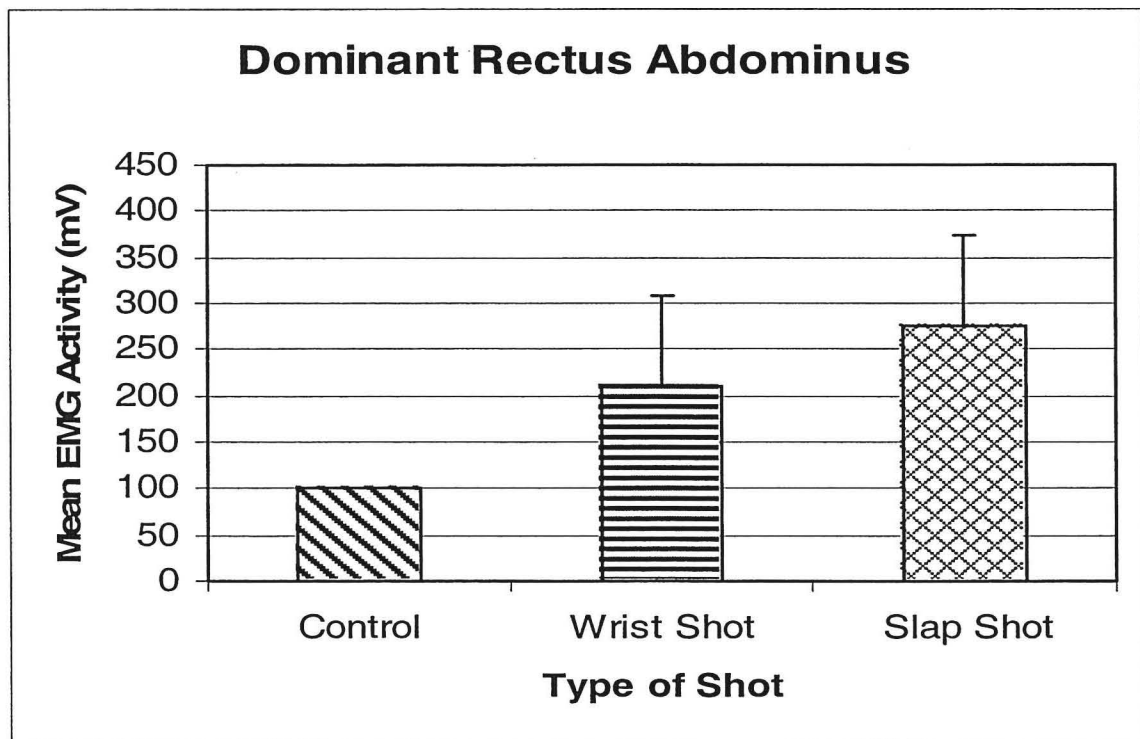


Figure 4.3. EMG activity of dominant rectus abdominus during shots (n=7)

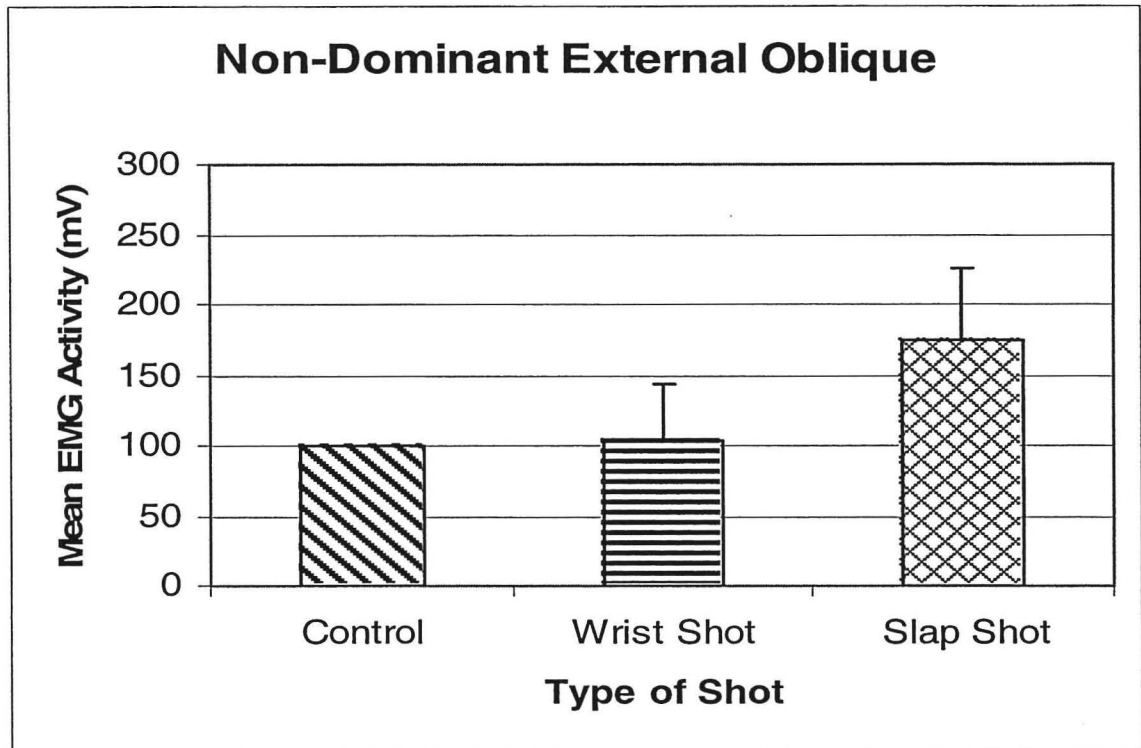


Figure 4.4. EMG activity of non-dominant external oblique during shots (n=7)

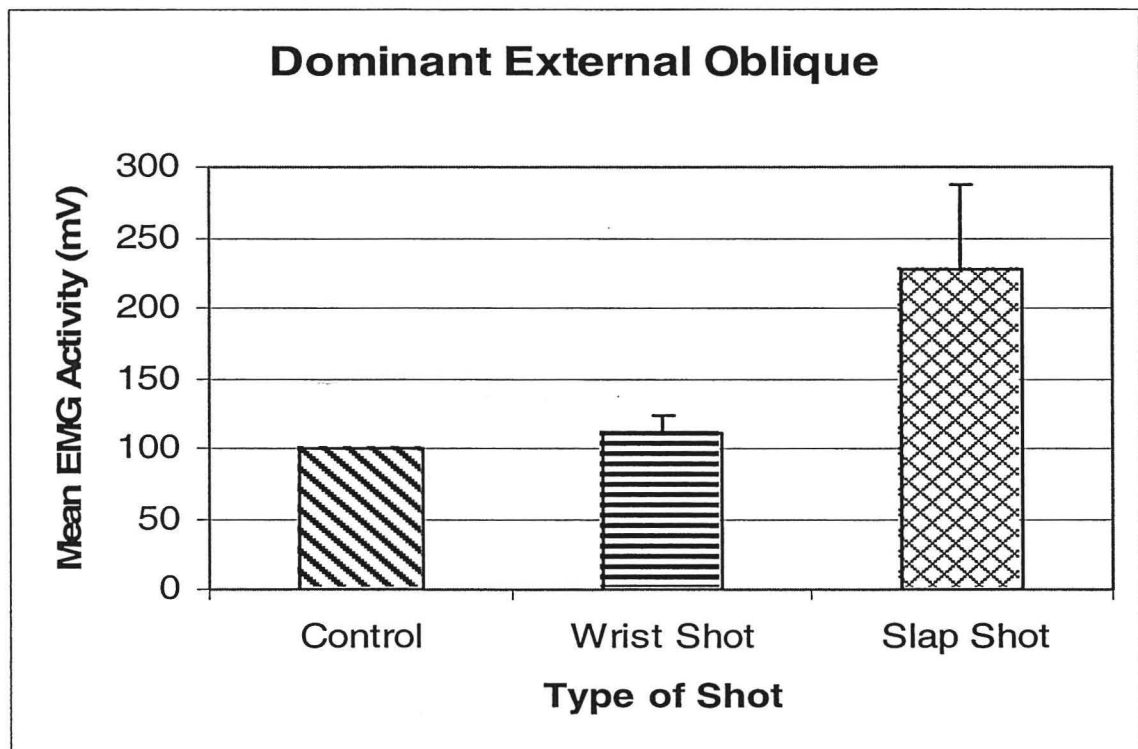


Figure 4.5. EMG activity of dominant external oblique during shots (n=7)

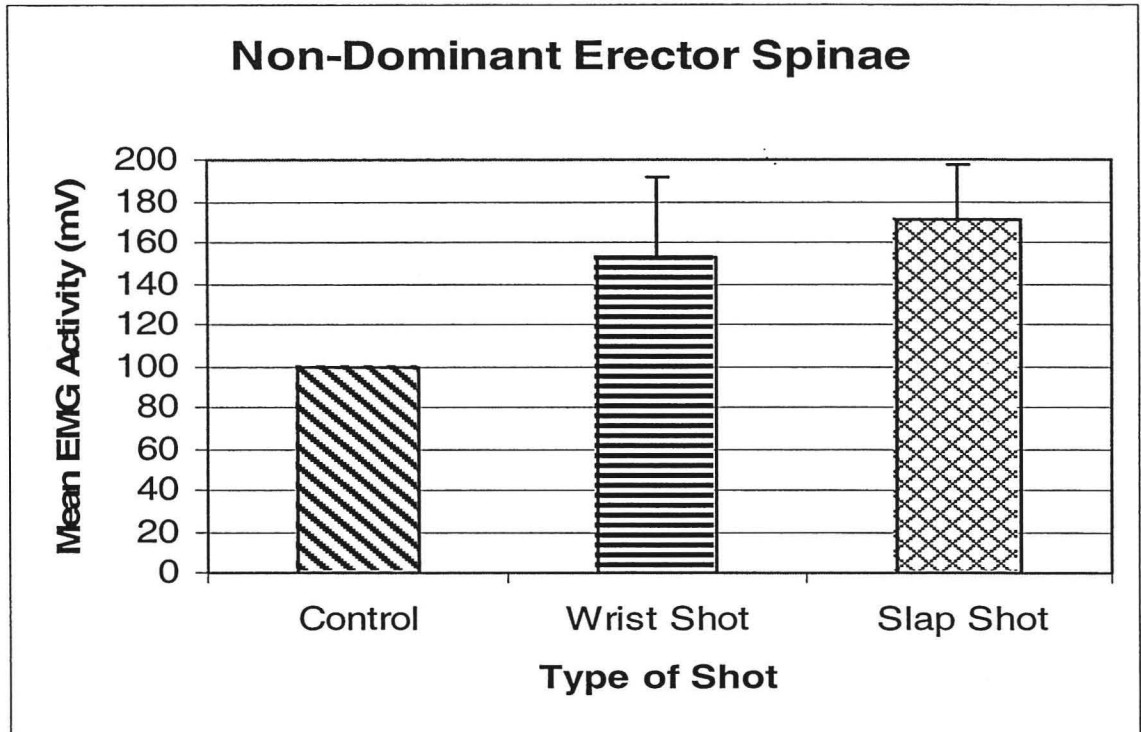


Figure 4.6. EMG activity of non-dominant erector spinae during shots (n=7)

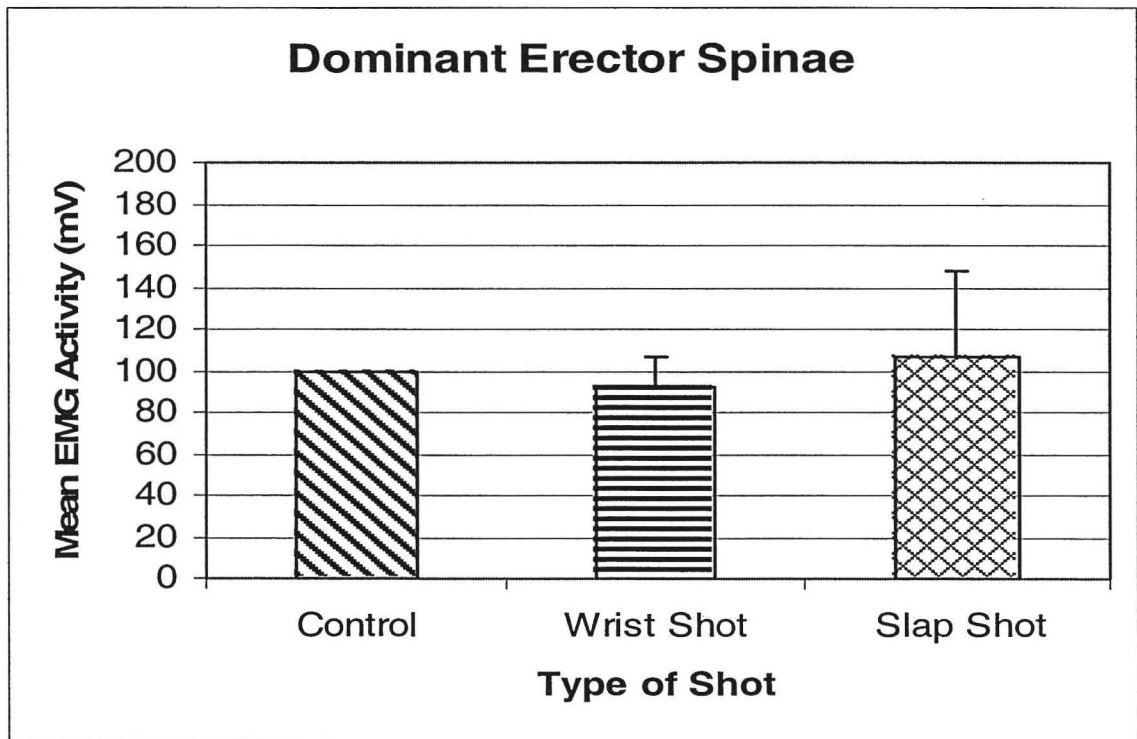


Figure 4.7. EMG activity of dominant erector spinae during shots (n=7)

CHAPTER V

DISCUSSION AND CONCLUSION

Seven Division I female hockey players performed wrist and slap shots to compare EMG recruitment during two main shots of scoring in hockey. The shots were performed on dry land at the beginning of the collegiate hockey season. The results demonstrate that the female players utilized a significantly higher level of EMG activity during the slap shot compared to the wrist shot. Surprisingly, the core muscles of trunk rotation, such as the external obliques, were recruited to a similar degree as the rectus abdominus and erector spinae muscles—primary flexors and extensors respectively. This study appears to be the first to assess the trunk muscle recruitment of female hockey players at this level of competition.

By definition, the slap shot is performed at a higher velocity than the wrist shot.⁹ The mechanics of the slap shot require that recruited muscle fibers contract at a higher velocity than during a wrist shot. This increase in muscle shortening velocity during the slap shot correlates to an increase in EMG activity. Potvin²² studied the effects of muscle kinematics on surface EMG amplitude and frequency during fatiguing dynamic contractions. It was found that concentric EMG amplitudes were observed to be higher than eccentric values due to the influence of velocity on force-generating capacity. The largest concentric EMG increases were observed at higher joint velocities, and eccentric increases were related to decreases in velocity. In another study by Ralston,²³ it was shown that as velocity increases, EMG activity will also increase.

Golf swings are very similar in appearance to the hockey slap shot. The phases of the golf swing include the take away, forward swing, acceleration, and follow through.

increases were related to decreases in velocity. In another study by Ralston,²³ it was shown that as velocity increases, EMG activity will also increase.

Golf swings are very similar in appearance to the hockey slap shot. The phases of the golf swing include the take away, forward swing, acceleration, and follow through. The hockey slap shot also includes components of a windup, downswing, and follow-through. Golf EMG studies by Young-Tae¹⁵ and Horton¹⁹ indicate that the obliques and erector spinae muscles demonstrated relatively high activity bilaterally throughout the golf swing, while the back muscles may primarily contract for stabilization and the abdominal muscles may contract for trunk flexion and rotation. By comparison, the slap shot in female hockey players results in relatively higher rectus abdominus activation. Unlike the golf shot, hockey players contact the ice prior to the puck in an attempt to “cock” or load the hockey stick. The loading is an attempt to increase potential energy retained in the “cocked” stick shaft just prior to puck contact. The downward force of “cocking” the hockey stick on the ice may partially explain differences in trunk muscle recruitment between golf and hockey shots. Additionally, results found by Bulbulian¹⁷ indicate that there is a difference in EMG activity of lumbar, oblique, latissimus dorsi, and pectoralis muscles when a golf swing is altered. A shorter backswing of a golfer attempting to reduce stress and strain on the spine and spinal musculature activates more shoulder muscular rather than trunk musculature. In a right-handed swing, all muscles except the right oblique showed the greatest activation in the acceleration phase. This may reduce trunk muscle activation and possibly reduce back injury and pain.

Although significance was not found, the external oblique muscles demonstrated a higher increase in mean EMG activity when compared to the rectus abdominus and

erector spinae muscles during performance of each hockey shot. Higher levels of external oblique activity, as is also seen in the golf swing, supports the contention that trunk rotation is a primary component to both the wrist and slap shot. Although the increases in external oblique activity were not significant, further research using larger sample sizes may augment understanding of the role of trunk rotation and stabilization during hockey shots.

Limitations

Parametric statistical analysis, as utilized in this study, estimates population parameters if certain basic assumptions are satisfied. One assumption is that the treatment populations are normally distributed. Another assumption is that the normal distributions have the same standard deviation or variance. A third assumption is that the data is taken from an interval or ratio scale. A primary limitation to this study was that only seven subjects were included in the test population. This relatively small sample size may have affected the parametric statistical assumption that the test population was normally distributed. When one or more assumptions of a parametric analysis fail to be met, non-parametric tests that make use of fewer assumptions can be utilized. However, it is generally accepted that results from parametric tests will continue to hold validity even when one or more of the assumptions previously described are compromised. Parametric tests are consistently viewed as being more powerful than non-parametric tests, leading researchers to justify the continued use of such tests despite initial requirements not being met.²⁴

All debates over which tests to use aside, the use of a larger subject pool ($n \geq 30$ is often considered satisfactory) would meet the assumption of normal distribution and

contribute to acceptance of valid test results. When limits are present in terms of time and resources in collecting data, reaching a sample size of at least thirty subjects may be unrealistic. In such instances, it may be more realistic to estimate the necessary sample size by specifying a level of significance and desired power prior to data collection. Through the use of power analysis, one can predict the number of subjects needed to show significance in a study by using the standard deviation. Usually when a study has low subject numbers, resulting power of the study will also be low. This results in the inability to find significant differences among test variables. Although this study utilized a relatively low subject count, a high degree of power was found during the data analysis. This strengthens the argument that the results from this study were valid despite the few subjects participating.²⁴

Another limitation is that the subjects performed the requested hockey shots on land instead of on ice, the natural playing surface of hockey. Similarly, the players were required to perform their shots in a stationary position instead of shooting the puck while moving forward which is part of the natural shot. The EMG transmitters were attached to the body of each subject, and this may have contributed to inhibition of the player's natural swing progression.

Recommendations for future studies include wider analysis to include muscles that might also contribute to the slap and wrist shots such as thigh, hip, shoulder, and arm muscles. Future studies might also employ the use of a natural playing environment including: ice rink, full hockey equipment, and skating speed to eliminate modifications to EMG activity made in an unnatural environment.

Clinical Implications

It is important to train athletes with sport specific exercises to allow for adequate preparation for game situations. Hockey consists of high velocity movements that are initiated and stopped quickly either during shot production or skating. The trunk musculature is characterized as acting under ballistic conditions, especially during sports. The definition of ballistic movement is an exercise or sports-related movement in which part of the body is “thrown” against the resistance of antagonist muscles or against the limits of a joint.²⁵ The latter is considered to be very dangerous to the integrity of the ligaments, capsule, and tendons surrounding the joint. It is important to complete ballistic training of muscles using sport specific exercises for two reasons: to prevent movements from causing micro or macrotrauma, and to provide advantage during sport such as increased velocity, timing, and force throughout an action. This is very crucial during all actions of a hockey game.

The trunk musculature protects the body during movements with this extreme exertion.²⁶ In addition to acting as the antagonist muscles stopping the ballistic movement, athletes instinctively exhale against a closed glottis producing a valsalva maneuver. This exhalation creates a greater intra-abdominal pressure which in turn stabilizes the lumbar spine.

The significant role of the trunk muscles during each hockey shot, as evident through the data found in this study, justifiably implies reasons to specifically train them under ballistic conditions. It is suggested that flexor-rotators (external obliques) should be prioritized during training over pure flexors (rectus abdominus), due to the fact that most athletic activities involve a rotational component along with flexion. This training

will both increase the velocity and power of the shot, but also decrease the likelihood of injury during all hockey movements.

Conclusion

The purpose of this study was to investigate the trunk muscles' activation patterns in women hockey players during the performance of the slap shot and the wrist shot as well as whether there is a significant difference in trunk activation between the two different shots. It was found that there was a significant difference in mean EMG when the slap and wrist shot were compared, but there was no significant difference between individual muscles during each shot.

This data could help the development of future studies in women's hockey as well as constitute reasons that trunk musculature exercises should be implemented in a training program specifically designed for hockey players for both higher velocity and power of shots as well as injury prevention due to the ballistic nature of the sport.

APPENDIX A

University of North Dakota Human Subjects Review Form

All research with human participants conducted by faculty, staff, and students associated with the University of North Dakota, must be reviewed and approved as prescribed by the University's policies and procedures governing the use of human subjects. It is the intent of the University of North Dakota (UND), through the Institutional Review Board (IRB) and the Office of Research and Program Development (ORPD), to assist investigators engaged in human subject research to conduct their research along ethical guidelines reflecting professional as well as community standards. The University has an obligation to ensure that all research involving human subjects meets regulations established by the United States Code of Federal Regulations (CFR). When completing the Human Subjects Review Form, use the "IRB Checklist" for additional guidance.

Please provide the information requested below:

Principal Investigator: David Relling, PT, PhD, Lon Donald, Kristi Kjellgren, Jodi Young, Michael Young /

Telephone: (701) 777-2831 E-mail Address: drelling@medicine.nodak.edu

Complete Mailing Address: 501 N Columbia Rd, Box 9037

School/College: School of Medicine and Health Sciences Department: Physical Therapy

Student Adviser (if applicable): David Relling, PT, PhD

Telephone: (701) 777-4091 E-mail Address: drelling@medicine.nodak.edu

Address or Box #: 502 N. Columbia Rd, Box 9037

School/College: School of Medicine and Health Sciences Department: Physical Therapy

Project Title: Electromyographic (EMG) and Motion Analysis of Trunk Muscles at the point of Puck Contact

During Slap and Wrist Shots by Female Ice Hockey Athletes

Proposed Project Dates: Beginning Date: 4/27/2004 Completion Date: 4/20/2005
(Including data analysis)

Funding agencies supporting this research: _____

(A copy of the funding proposal for each agency identified above MUST be attached to this proposal when submitted.)

Does the Principal Investigator or any researcher associated with this project have a financial interest in the results of this project? If yes, please submit, on a separate piece of paper, an additional explanation of the financial interest (other than receipt of a grant)
 YES or X NO

If your project has been or will be submitted to other IRB's, list those Boards below, along with the status of each proposal.

Date submitted: _____ Status: Approved Pending

Date submitted: _____ Status: Approved Pending

Type of Project: Check "Yes" or "No" for each of the following.

 X YES or NO New Project YES or X NO Dissertation/Thesis
 YES or X NO Continuation/Renewal X YES or NO Student Research Project
 YES or X NO Is this a Protocol Change for previously approved project? If yes, submit a signed copy of this form with the changes bolded or highlighted.
 YES or X NO Does your project involve medical record information? If yes, complete the HIPAA Compliance Application and submit it with this form.
 YES or X NO Does your project include Genetic Research? If yes, refer to Chapter 3 of the Researcher Handbook for additional guidelines regarding your topic.
 YES or X NO Does your project include Internet Research? If yes, refer to Chapter 3 of the Researcher Handbook for additional guidelines regarding your topic.
 YES or X NO Will subjects or data be provided by Altru Health Systems? If yes, submit two copies of the proposal. A copy of the proposal will be provided to Altru.

Will research subjects be recruited at another organization (e.g., hospitals, schools, YMCA) or will
____ YES or X NO assistance with the data collection be obtained from another organization?

If yes, list all institutions: _____

Letters from each organization must accompany this proposal. Each letter must illustrate that the organization understands their involvement in that study, and agrees to participate in the study. Letters must include the name and title of the individual signing the letter and, if possible, should be printed on letterhead.

Subject Classification: This study will involve subjects who are in the following special populations: Check all that apply.

____ Minors (< 18 years)	<u>X</u> UND Students
____ Prisoners	____ Pregnant Women/Fetuses
____ Persons with impaired ability to understand their involvement and/or consequences of participation in this research	
____ Other _____	

For information about protections for each of the special populations, refer to Chapter 5 of the Researcher Handbook.

This study will involve: Check all that apply.

____ Deception	____ Stem Cells
____ Radiation	____ Discarded Tissue
____ New Drugs (IND)	____ Fetal Tissue
____ Non-approved Use of Drug(s)	____ Human Blood or Fluids
____ Recombinant DNA	____ Other _____
<u>X</u> None of the above will be involved in this study	

I. Project Overview

In 1991, there were 5,573 registered female hockey players in the United States. Currently this number has grown to 40,000 female hockey players, and this total is only expected to grow exponentially in the future. Despite the popularity of the sport among females, there is little research related to this population. Specifically, there is a lack of research on trunk muscle activity during shooting in women's hockey. The purpose of our study is to determine the activity of trunk musculature at the point of contact during the wrist shot and slap shot. The results of this study will serve as an initial step in understanding the recruitment and activation pattern of the trunk muscles during these two primary methods of scoring. Healthy human subjects that are familiar with the mechanics of the sport are necessary to determine which muscles are active and when they are active while performing these different hockey shots.

We hypothesize that the slap shot will demonstrate increased electromyography (EMG) activity in the trunk muscles when compared to the wrist shot. The results of the study will attempt to provide information for establishing training and conditioning programs targeting trunk musculature. This information will be beneficial to future physical therapist students and professionals in the development of potential training and/or rehabilitation guidelines for female hockey players.

II. Protocol Description

1. Subject Selection.

The sample subjects will consist of up to 30 female hockey players over the age of 18 without any current injuries or medical conditions that would inhibit the ability to complete a normal hockey shot. All subjects will complete an appropriate human subject consent form, as well as a subject questionnaire to determine level of hockey experience and demographic data.

2. Description of Methodology.

This study will take place at a local ice arena. Upon entering the testing site, the subjects will be given verbal instructions on the procedures and purpose of the study. They will also be asked to complete a consent form and subject questionnaire. Dave Relling, Lon Donald, Kristi Kjellgren, Jodi Young, and Michael Young will carry out the research procedures as instructed during instrumentation class.

To protect the privacy of our subject pool, self adhesive EMG electrodes and motion analysis markers will be applied in a locker room. The electrodes will be placed bilaterally over the motor points of Erector Spinae, Rectus Abdominus, and External Oblique Musculature. If necessary, body hair will be clipped and the skin cleaned with alcohol before placement of the electrodes to ensure good conduction. The motion analysis self-adhesive markers will be placed on bony landmarks of the subject including the acromion, greater trochanter, lateral femoral condyle, lateral malleolus, and pelvis. Motion analysis markers will also be placed on the shaft and blade of the hockey stick.

The EMG signals will be transmitted to a receiver unit, and then fed into a computer for display, recording, and analysis of data. Maximal voluntary contractions (MVC) of the muscles will be measured using manual muscle testing techniques administered by one of the testers. This procedure will require specific positioning and maintenance of a constant amount of resistive force for each muscle. This contraction will represent 100% of electrical activity, and will normalize EMG data during analysis.

After the placement of electrodes, the transmitter unit will be secured to the thigh or waist of the subject with a belt. The subjects will then complete six warm-up shots (three wrist shots, three slap shots) prior to the collection of data to ensure subject comfort and an unobstructed shot. Following the warm-up session, the subjects will randomly select the shot sequence that will be performed for data collection. For each type of shot, the subjects will be directed to perform five normal shots from a distance of thirty feet directly in front of the net. The total number of shots for each subject will be 16-20 including warm-ups. All shots will make contact with a real puck as though the subject was trying to score a goal. Point of contact with the hockey puck will be determined through use of motion analysis.

Data collection will consist of measurements of muscle activity around the trunk and low back. The mean of the five repetitions for each shot will be statistically analyzed for each of the monitored muscles and then expressed as a percentage of EMG activity recorded during the MVC. Muscle activity will be compared between the two types of shots by using traditional statistical analysis to determine the effect of shot type and muscle on mean EMG activity and area under the curve. Statistical significance will be set at a level of 0.05. The time required for subjects to complete the study will be approximately one hour.

Subject Questionnaire Form - attached

3. Risk Identification.

Physical risk to subjects of this study is minimal. EMG poses no risk and muscle strains are possible but unlikely due to the ability and health as well as the warm-up period allotted of the subjects. Subject consent and data forms will be marked with code numbers rather than names to allow subject confidentiality. Participation in this study is voluntary and subjects are free to withdraw at any time for any reason without fear of retribution.

4. Subject Protection.

All possible precautions will be taken to minimize potential risks to the subjects such as providing a warm-up period, use of identification numbers, and retaining data and consent forms in separate locked sites within the physical therapy department. The subjects will be provided with a copy of the consent form and the testing procedure will be thoroughly explained to them before testing.

All data will be collected and remain confidential for three years following this study in the UND physical therapy department, keeping subject personal data and consent forms separate. Subjects will be assigned code numbers to assure confidentiality and eliminate use of names. Only the authors of this study and people who audit IRB procedures will have access to this data. The data will be shredded three years following the conclusion of the study.

III. Benefits of the Study

Upon completion of this study, the activity of the trunk muscles at the point of puck contact will be determined during two different hockey shots. Knowledge of the trunk musculature recruitment and activity patterns during various shots will serve as a foundation for future studies involving female hockey players. The results of this study may also lead to a deeper understanding of the female hockey shot process and development of sports specific training programs.

IV. Consent Form

Attached

By signing below, you are verifying that the information provided in the Human Subjects Review Form and attached information is accurate and that the project will be completed as indicated.

Signatures:

(Principal Investigator)

Date:

(Student Adviser)

Date:

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

Date: 4/21/2004

Project Number: IRB-200404-316

Principal Investigator: Relling, David; Donald, Lori; Kjellgren, Kristi; Young, Jodi; Young, Michael

Department: Physical Therapy

Project Title: Electromyographic (EMG) and Motion Analysis of Trunk Muscles at the Point of Puck Contact During Slap and Wrist Shots by Female Ice Hockey Athletes

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on April 22, 2004 and the following action was taken:

☒ Project approved. Expedited Review Category No. 4 & 7

Next scheduled review must be before: April 22, 2005

☒ Copies of the attached consent form with the IRB approval stamp dated April 22, 2004 must be used in obtaining consent for this study.

☐ Project approved. Exempt Review Category No. _____

☐ This approval is valid until _____ as long as approved procedures are followed. No periodic review scheduled unless so stated in the Remarks Section.

☐ Copies of the attached consent form with the IRB approval stamp dated _____ must be used in obtaining consent for this study.

☐ Minor modifications required. The required corrections/additions must be submitted to ORPD for review and approval. This study may NOT be started UNTIL final IRB approval has been received.
(See Remarks Section for further information.)

☐ Project approval deferred. This study may not be started until final IRB approval has been received.
(See Remarks Section for further information.)

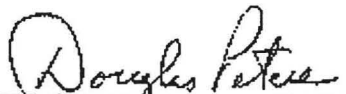
REMARKS: Any adverse occurrences in the course of the research project must be reported immediately to the IRB Chairperson or ORPD.

Any changes in protocol or Consent Forms must receive IRB approval prior to being implemented. You must submit a memo with a copy of the Consent Form and a revised Human Subjects Review Form, with the appropriate signatures, to the Office of Research and Program Development for review and approval.

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature. All revisions MUST be highlighted.

☒ Education Requirements Completed. (Project cannot be started until IRB education requirements are met.)

cc: Chair; Physical Therapy



Signature of Designated IRB Member
UND's Institutional Review Board

4/22/04

Date

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact ORPD to obtain the required documents.

(Revised 10/2002)

INFORMATION AND CONSENT FORM

TITLE: Electromyographic and Motion Analysis of Trunk Muscles at the Point of Puck Contact During Slap and Wrist Shots by Female Ice Hockey Athletes

You are being invited to participate in a study conducted by Dr. Dave Relling, project advisor, and Lon Donald, Kristi Kjellgren, Jodi Young and Michael Young, physical therapy students at the University of North Dakota. The purpose of this study is to describe the quantity and quality of trunk muscle recruitment during two methods of shooting in hockey: slapshot and wrist shot. In the future, the conclusions drawn from this study could help other physical therapy students and therapists determine which muscles need to be specifically trained to help with increased strength for varying hockey shots, as well as to define the muscles role in the hockey shot. Only normal, healthy female subjects that are familiar with the mechanics of the sport, at least eighteen years old, are not pregnant and have no history of trunk musculature problems or injury will be asked to participate in this study.

Subjects will be asked to report to a local ice arena or the UND physical therapy department at an assigned time. Self-adhesive EMG electrodes will be applied to your lower back and abdomen for recording muscle activity. The electrodes do not stimulate the skin. Self-adhesive markers will be placed on bony landmarks of the shoulder, pelvis and leg for motion analysis. Clipping of the hair and cleaning of the skin at the area where the electrodes will be placed may be necessary to assure appropriate electrical conduction. You will then be positioned to conduct a maximal muscle contraction of the different muscles under study. Electrode preparation and maximal muscle contractions will be performed in a private environment, such as a locker room or training room to ensure confidentiality and modesty during the procedures. Maximal muscle contractions of the low back and abdomen-- including the rectus abdominus, external oblique and erector spinae muscles, will be held for six seconds. After performing the maximal muscle contractions, you will be asked to perform a randomized series of different hockey shots-- slapshot and wrist shot. You will be able to take five warm-up shots for each of the two shot types. After this point, you will then be asked to perform five repetitions of the slapshot and wrist shot. This study will take approximately one hour of your time. During the experiment, we will be recording the amount of muscle activity you have in your rectus abdominus, external oblique and erector spinae muscles while videotaping the performance of the two different hockey shots.

Although the process of physical performance testing always involves some degree of risk, the investigators in this study feel that the risk of injury or discomfort is minimal. No adverse effects are expected however, there is a possibility of skin redness or irritation where the electrodes are placed due to reaction to the adhesive material. No costs are anticipated to you in this study.

University of North Dakota
Institutional Review Board

Approved on APR 22 2004

Expires on APR 21 2004

Your name will not be used in any reports of the results of this study. Any information that is obtained for this study and can identify you will be kept confidential and will only be disclosed with your permission. The data will be identified by a code number that is only known to the investigators. The investigators or subject may stop the experiment at any time if the subject is experiencing discomfort, pain, fatigue or other symptoms that may be detrimental to her health. The subject's decision on whether or not to participate will not prejudice your current or future relationship to the Physical Therapy Department or the University of North Dakota. The data and records collected from this study will be kept in separate, locked rooms in the University of North Dakota Physical Therapy Department for three years following the completion of this study. Only Dr. Dave Relling, Lon Donald, Kristi Kjellgren, Jodi Young, Michael Young and people who audit IRB procedures will have access to the data. After three years, the data and records will be destroyed according to department policy.

The investigators involved are available to answer any questions you have concerning this study. In addition, you are encouraged to ask any questions concerning this study that you may have in the future, such as being informed of study results. Questions may be asked by calling Dr. Dave Relling at (701) 777-4091 or Lon Donald, Kristi Kjellgren, Jodi Young, and Michael Young at (701) 777-2831. If you have any other questions or concerns, please call the Office of Research and Program Development at (701) 777-4279. A copy of this consent form is available to all subjects in this study.

In the event that this research activity results in a physical injury, medical treatment will be available including first aid, emergency treatment and follow-up care as it would be to any member of the general public in similar circumstances. Payment, if any, for any such treatment must be provided by you or your third party payer.

ALL OF MY QUESTIONS HAVE BEEN ANSWERED AND I AM ENCOURAGED TO ASK ANY QUESTIONS THAT I MAY HAVE CONCERNING THIS STUDY IN THE FUTURE. MY SIGNATURE INDICATES THAT, HAVING READ THE ABOVE INFORMATION, I HAVE DECIDED TO PARTICIPATE IN THE RESEARCH PROJECT.

I have read all of the above and willingly agree to participate in this study explained to me by Dr. Dave Relling, Lon Donald, Kristi Kjellgren, Jodi Young and Michael Young.

Participant's Signature

Date

Witness (other than the scientist)

Date

University of North Dakota
Institutional Review Board

Approved on APR 22 2004

Expires on APR 21 2004

Electromyographic and Motion Analysis of Trunk Muscles at the Point of Puck Contact
During Slap and Wrist Shots by Female Ice Hockey Athletes

Subject Questionnaire

- 1) How old are you? _____
- 2) How long have you played hockey competitively? _____
- 3) List previous teams as well as at what level you were playing (amateur, recreational, competitive, etc.)

- 4) What is your dominant (shooting) hand? (circle one)

Left Right

- 5) What is your height and weight?

Height _____

Weight _____

- 6) What position do you play usually? _____

- 7) List your previous and current injuries that may inhibit your ability to perform a normal hockey shot.

- 8) How much playing time did you have this last season? _____

- 9) How many goals did you score this last season? _____

- 10) Which type of shot do you prefer? (circle one)

Wrist Shot

Slap Shot

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